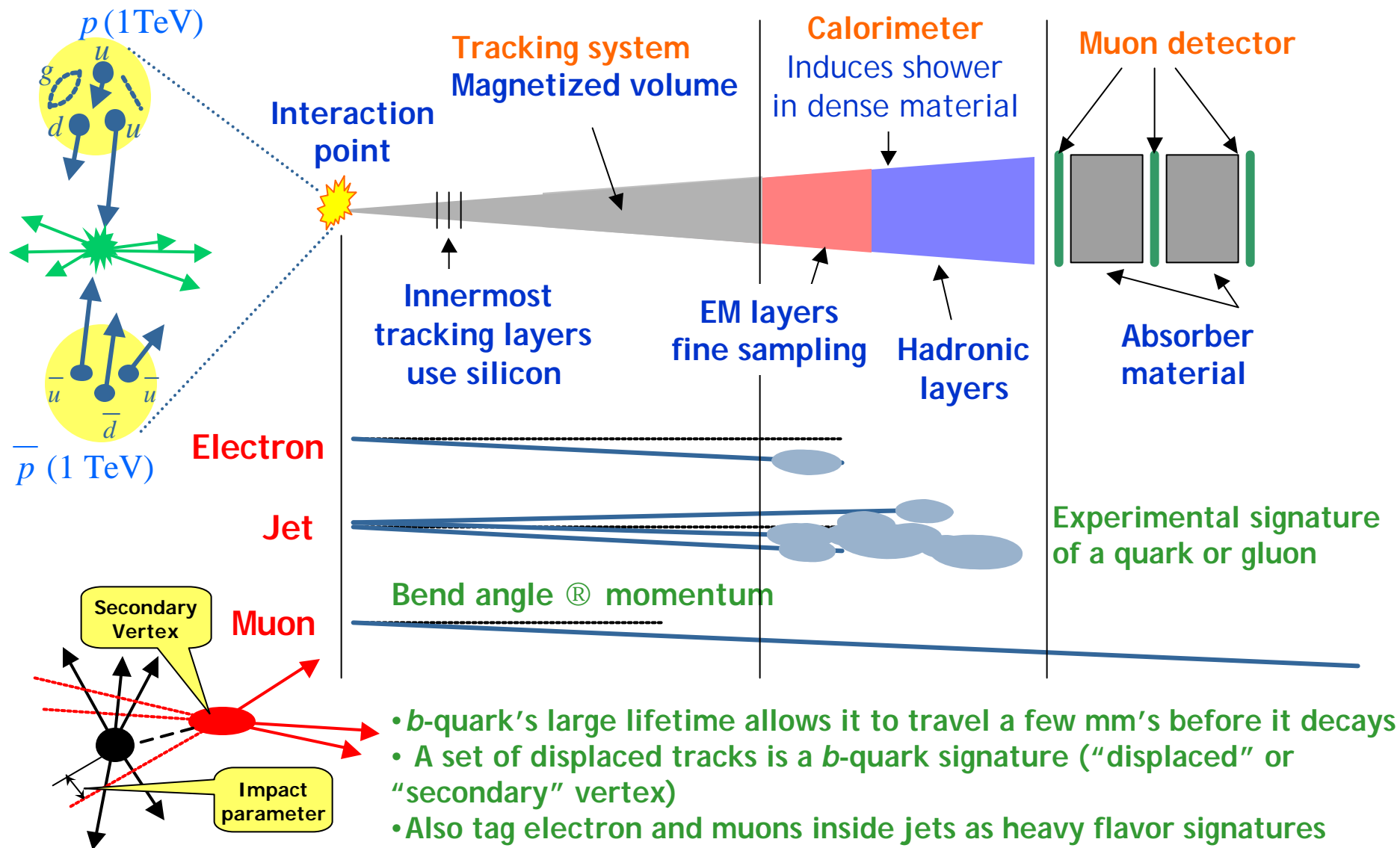# DØ Calorimeter Trigger

- **Part I - today**
  - Particle Interaction in a High Energy Physics Detector
  - DØ Liquid Argon Calorimeter
  - Run II Calorimeter Electronics
  - Tevatron Bunch Structure
  - Run II Timing
  - DØ Trigger Overview
  - Calorimeter Trigger
  - Motivation for Trigger Upgrade

- **Part II – next UIC Mtg**
  - Limitations and Solutions
  - Run IIb L1 CAL Trigger Design
  - UIC Contribution
  - Goals and Deadlines

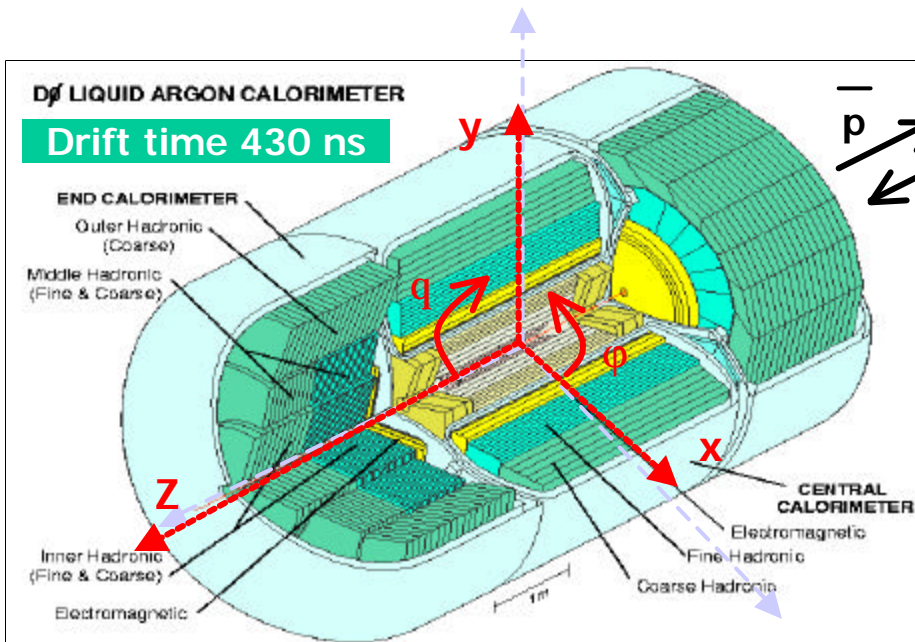**Most of the material presented today can be found on the Shifter Tutorial web page - http://www-d0.fnal.gov/runcoor/DAQ/**
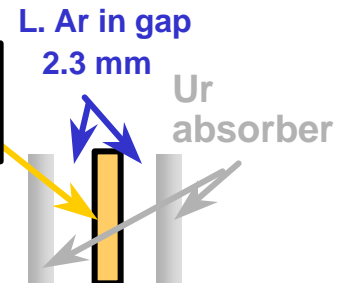
Identifying particles in a HEP detector

p (1TeV)

g u

d u

$\overline{u}$ $\overline{u}$

$\overline{d}$

$\overline{p}$ (1 TeV)

Interaction point

Tracking system
Magnetized volume

Calorimeter
Induces shower in dense material

Muon detector

Innermost tracking layers use silicon

EM layers fine sampling

Hadronic layers

Absorber material

Electron

Jet

Experimental signature of a quark or gluon

Bend angle ® momentum

Muon

Secondary Vertex

Impact parameter

- *b*-quark's large lifetime allows it to travel a few mm's before it decays
- A set of displaced tracks is a *b*-quark signature ("displaced" or "secondary" vertex)
- Also tag electron and muons inside jets as heavy flavor signatures

Liquid Argon Calorimeter

Drift time 430 ns

$\bar{p}$ ⟶ ⟵ p

Cu pad readout on 0.5 mm
G10 with resistive coat epoxy

L. Ar in gap
2.3 mm

Ur absorber

Run I Test beam energy resolutions

Electrons: $s_E / E = 15\% / \sqrt{E}$ (GeV) ⊕ 0.3%

Pions: $s_E / E \sim 45\% / \sqrt{E}$ (GeV) ⊕ 4%

- Each calorimeter cell consists of a liquid argon capacitor between an absorber plate and a G10 board.

- The G10 board has a high-resistivity coating to which a potential is applied with respect to the absorber plate to create the drift electric field.

- Particles transversing the gap produce and ionizing trail of electrons and ions. In the electric field the electrons drift towards the G10 coating, producing a current.

- The current induces an image charge on a copper pad etched on the G10 board under the resistive coat. A readout cell is formed from many pads grouped together.
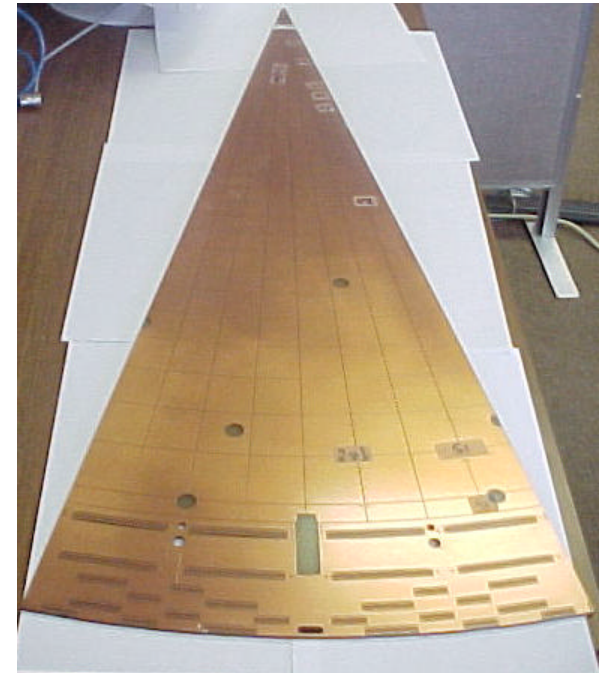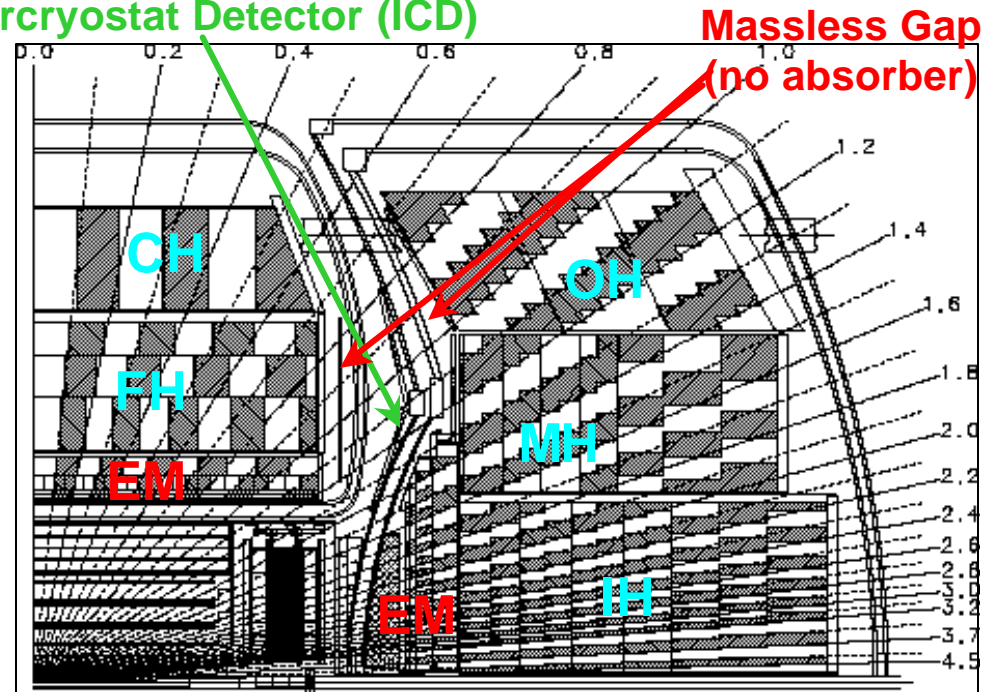
Calorimeter Segmentation

- **50k readout cells (<0.1% bad)**
- **Arranged in semi-projective towers**
- **Readout cells ganged in layers**
- **Readout segmented into $\mathbf{h}$, $\mathbf{f}$ for charge detection**
  - **Transverse segmentation $d\mathbf{h} \times d\mathbf{f} = 0.1 \times 0.1$**
  - **At shower max. (EM3) $d\mathbf{h} \times d\mathbf{f} = 0.05 \times 0.05$**
- **5k semi-projective towers**
  - **4 EM, 4-5 Hadronic (fine and coarse) layers**
- **Field +2.5 kV (E = 11 kV/cm)**
  - **drift time ~ 450 ns**
- **L1/L2 fast Trigger readout 0.2x0.2 towers**

Layer	CC	EC
EM1,2,3,4	X_O : 2,2,7,10 3mm Ur	X_O : (0.3),3,8,9 (1.4mm Fe) 4mm Ur
FH1,2,3,(4)	$\mathbf{l}_O$: 1.3,1.0,0.9 6mm Ur	$\mathbf{l}_O$: 1.3,1.2,1.2,1.2 6mm Ur
CH1,(2,3)	$\mathbf{l}_O$: 3.0 46.5mm Cu	$\mathbf{l}_O$: 3.0, (3.0, 3.0) 46.5mm Fe

Intercryostat Detector (ICD)

Massless Gap (no absorber)

CH
OH
FH
MH
EM
EM
IH

55k dual FET Preamplifiers

new calibrated pulse injection

new low noise preamp & driver

SCA analog storage > 4 msec, alternate

Trig. sum

Bank 0

BLS Card

SCA (48 deep)

SCA (48 deep)

Preamp/ Driver

Filter/ Shaper

x1

x8

Detector LAr cell

SCA (48 deep)

SCA (48 deep)

BLS

SCA

Output Buffer

ADC

Bank 1

Replace cables for impedence match

Shorter shaping ~400ns

Additional buffering for L2 & L3
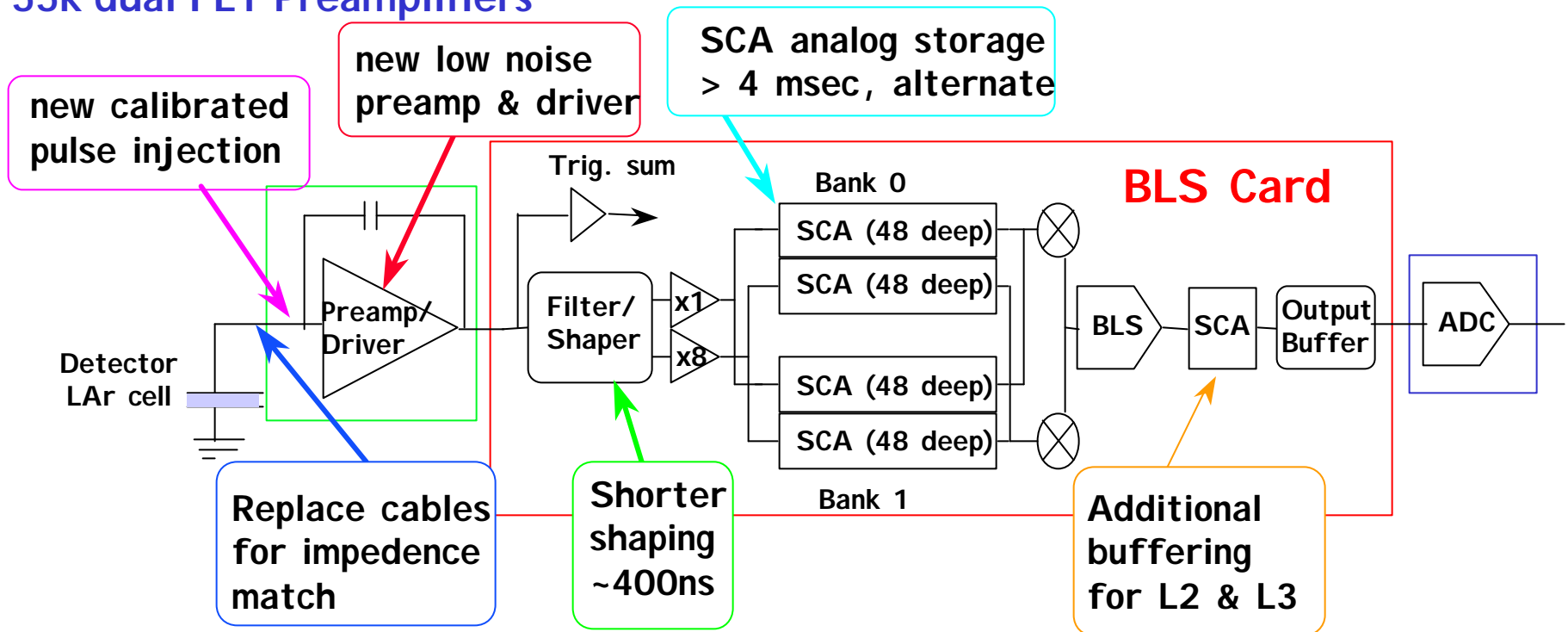
- **The signal from each cell is brought to a feed through port on a resistive coaxial cable. Then the signal is carried from the feed through port to the preamplifier inputs on twist and flat cables.**

- **These preamps are small hybrid ceramic printed circuits which are mounted on a printed circuit motherboard. There are 48 to a motherboard.**

- **The preamps integrate the charge produced by the calorimeter cells to produce voltages. The pulses of voltage are carried again by twist and flat cables to the shaper and baseline subtractor (BLS).**
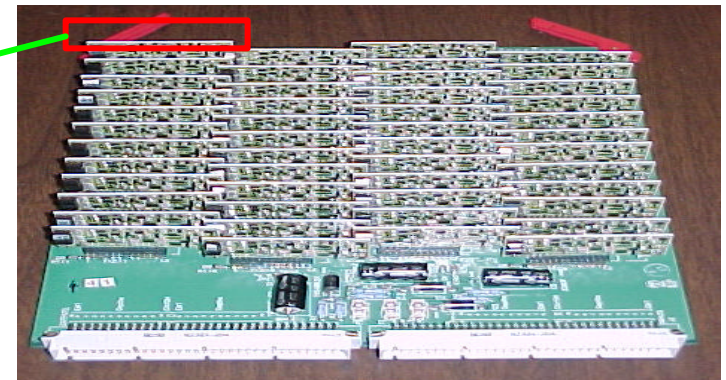
Preamplifier

- **New calorimeter preamp**
- **Hybrid on ceramic**
- **48 preamps on a motherboard**
- **New low-noise switching power supplies in steel box**

55296 hybrids
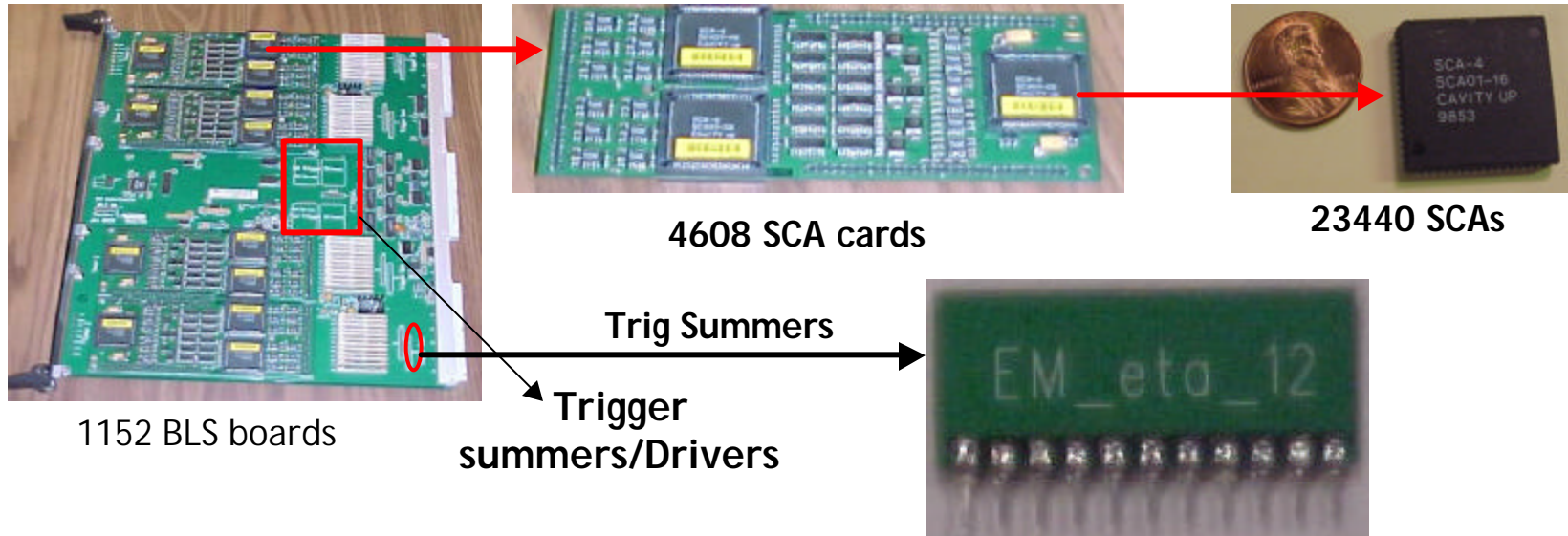
preamp   driver

FET

1152 boards

← 2" →
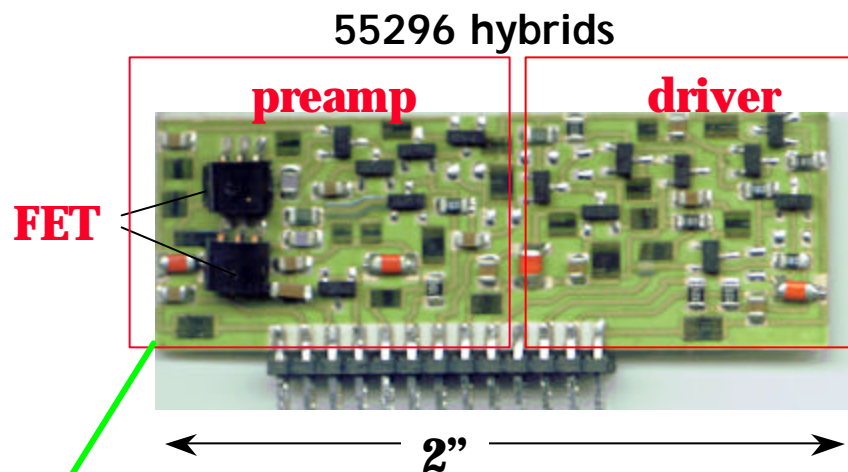
•Dual FET Frontend

•Compensation for Det. Cap.

•Faster Recovery Time

New output Driver for terminated signal

Base Line Subtracter (BLS)

4608 SCA cards

23440 SCAs

1152 BLS boards

Trig Summers

Trigger summers/Drivers

ADC's have 12 bit dynamic range. To achieve 15 bit dynamic range SCAs have low and high gain path for each readout channels (X8/X1)
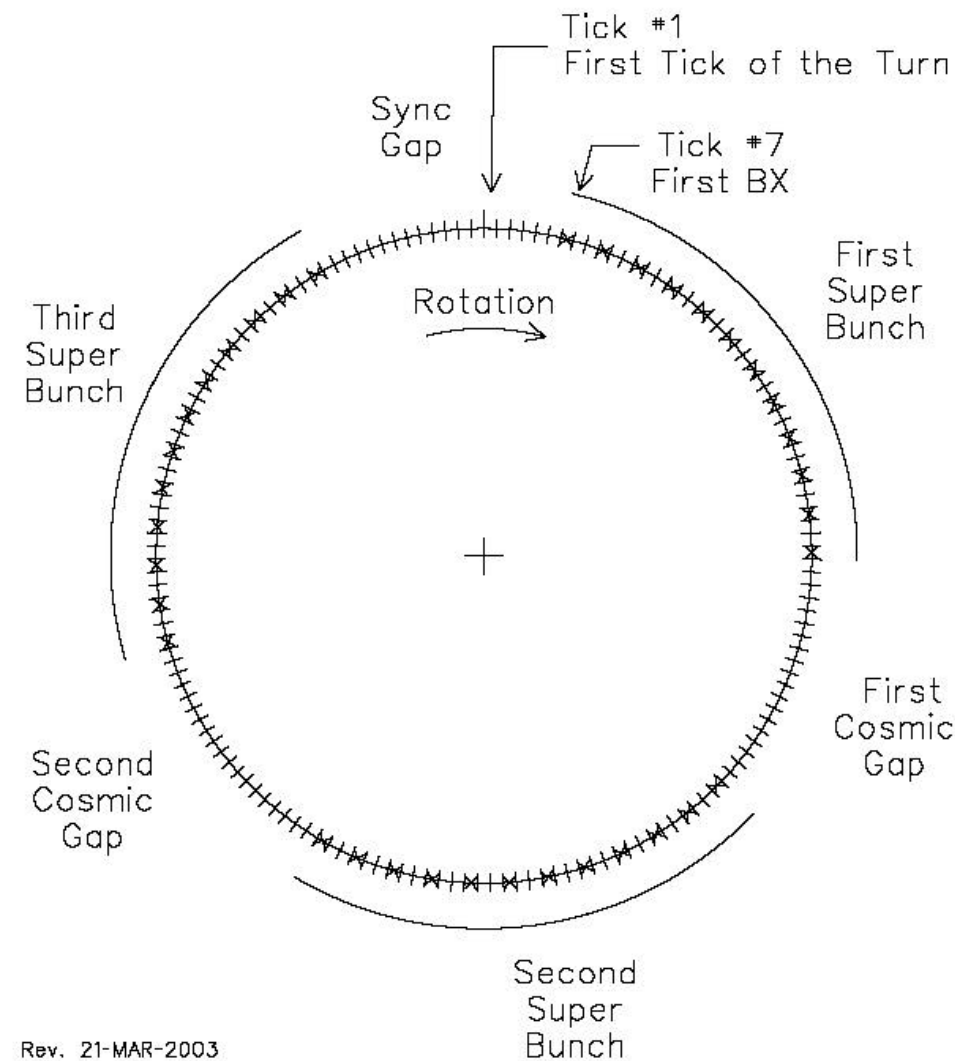
SCAs are not designed for simultaneous read/write operations. Two banks of SCAs, upper and lower (can't see in the picture), for alternate read/write operation.

Readout time ~6 μs (length of SCA buffers 132 X 46 >6 μs).

Trigger tower formation 0.2 X 0.2 for Level 1.

TeV RF = 53.104 MHz
Period = 18.83 nsec
1113 Cycles of TeV RF per Turn
RF Cycle == RF Bucket

BX == TeV Beam Crossing

Accelerator BX's can be no closer than once every 7 RF Buckets. Accelerator BX's spaced an integer number of 7 RF Bucket periods.

7 RF Buckets == 1 Tick
7 x 18.8 nsec = 132 nsec = 1 Tick
Ticks in a Turn are numbered 1:159
Tick rate = 7.59 MHz

In Run IIA there are 36 BX's per Turn
3 Super Bunches of 12 BX's each
During a Super Bunch there is a BX every 3 Ticks.
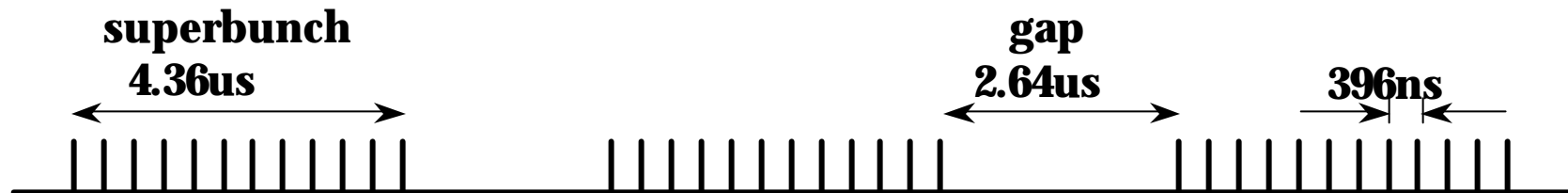3 fold symmetry:
B0 = CDF, D0, F0 = TeV RF

Diagram labels:
Tick #1 First Tick of the Turn
Sync Gap
Tick #7 First BX
First Super Bunch
Third Super Bunch
Rotation
First Cosmic Gap
Second Cosmic Gap
Second Super Bunch
Rev. 21-MAR-2003

Run II Tevatron Timing

Bunch structure

3.56us

gap used to form trigger
and sample baselines

Run I 6x6

superbunch
4.36us

gap
2.64us

396ns

Run II 36x36

Need to buffer information awaiting trigger decisions
This gap is too small to form trigger and sample
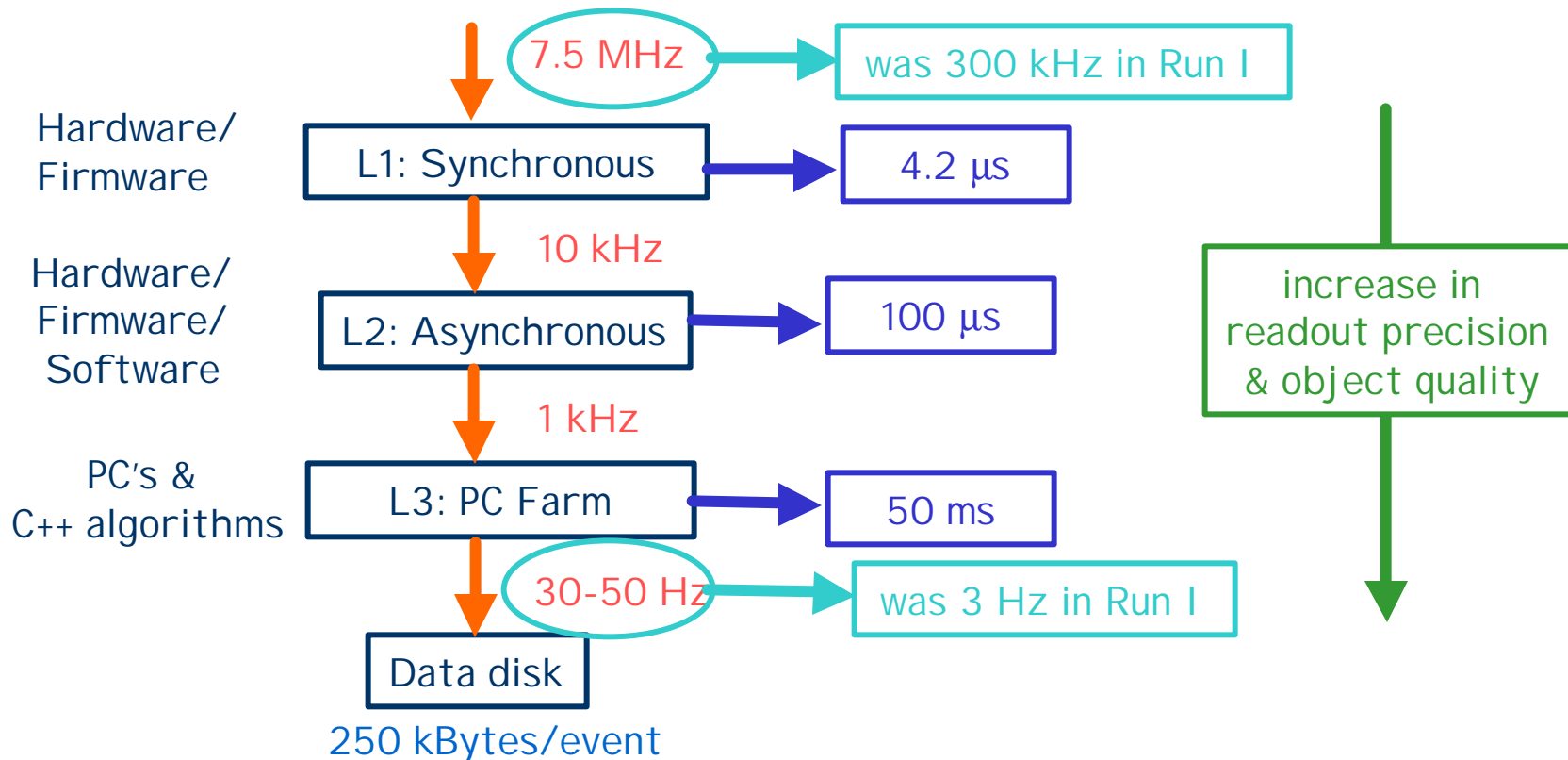**baseline for calorimeter**

- **Design all the electronics, triggers and DAQ to handle bunch structure with a minimum of 132ns between bunches and higher luminosity**

- **Maintain detector performance from Run I with higher rate, fluxes →need better precision, better triggers**
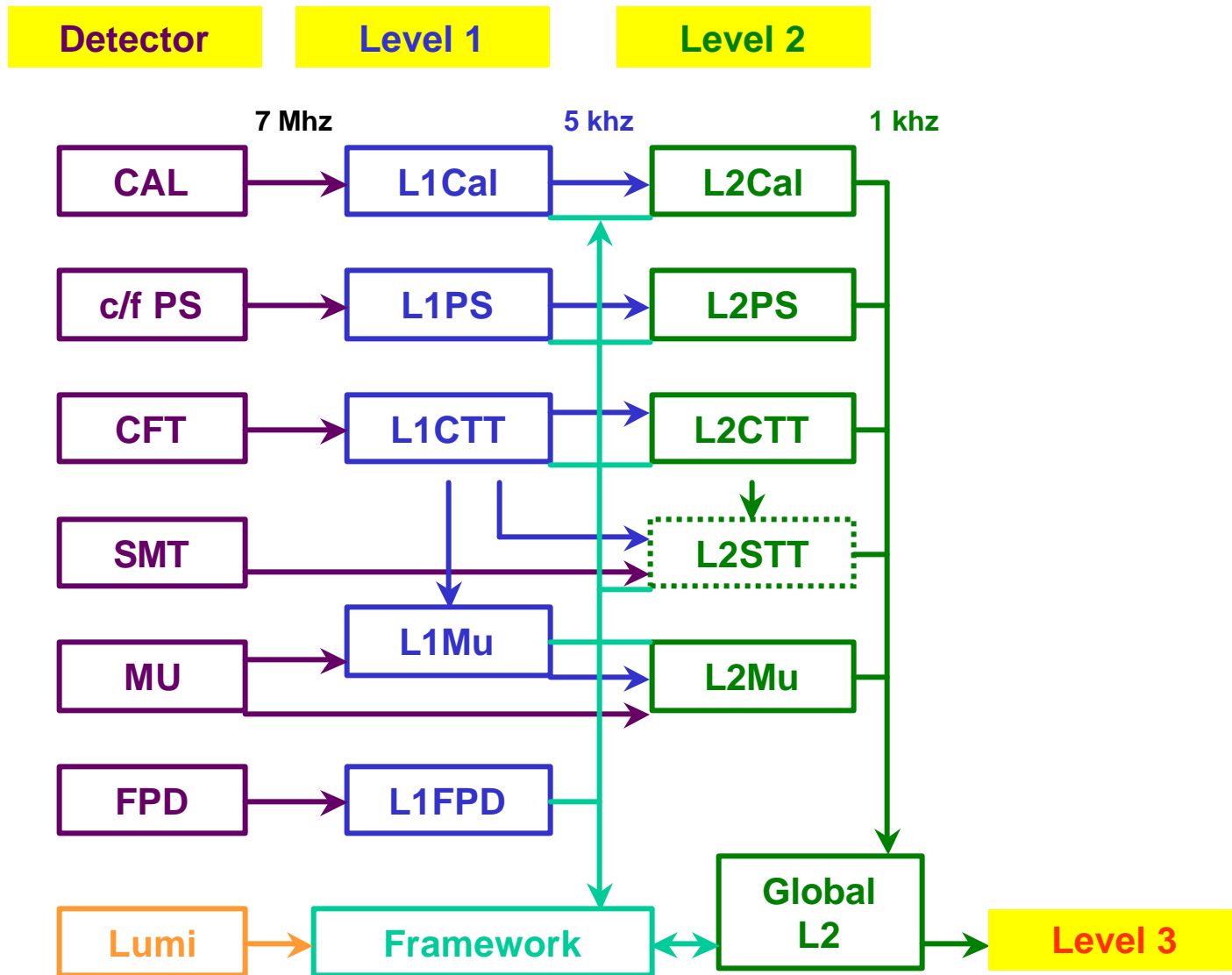
DØ Trigger Overview

- **There are 7.5M p-p crossings every second**
- **Huge data volume: 2 TB/sec – impossible to save all information on disk**
- **Focus on the "interesting" events: reduce data flow to 10-15 MB/sec**
- **Use modular system of three filtering levels**

At L = 2 x 10^{32} expect
4.4 W events/sec
5 tt events/hour and
7 W/ZH(100) events per day

Hardware/
Firmware

7.5 MHz → was 300 kHz in Run I

L1: Synchronous → 4.2 μs

10 kHz

Hardware/
Firmware/
Software

L2: Asynchronous → 100 μs

1 kHz

PC's &
C++ algorithms

L3: PC Farm → 50 ms

30-50 Hz → was 3 Hz in Run I

Data disk

250 kBytes/event

increase in
readout precision
& object quality

Detector **Level 1** **Level 2**

7 Mhz 5 khz 1 khz

CAL → L1Cal → L2Cal

c/f PS → L1PS → L2PS

CFT → L1CTT → L2CTT

SMT → L2STT

MU → L1Mu → L2Mu

FPD → L1FPD

Lumi → Framework ↔ Global L2 → Level 3

Calorimeter Trigger Objects

- **L1 Calorimeter Trigger is the primary mechanism for collecting: e/γ, Jets, Invisible Particles (MET)**

| Physics	Sample Channels	Cal Triggers
Electro-Weak	$W \circledR \lambda n / Z \circledR \lambda^+ \lambda^-$	EM, ME_T
Top	$t\bar{t} \to \lambda\nu + \text{jets, all jets}$ $Z \to b\bar{b}$	EM, Jet (calibrate E-scale)
B Physics	B_s **Mixing (hadronic)**	EM, Cal-Track
New Phenomena	$\tilde{\chi}_1^{\pm} \tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \lambda\nu \, \tilde{\chi}_1^0 \lambda^+ \lambda^-$ $\tilde{t}_1 \to bW^+ \tilde{\chi}_1^0, \quad G_{KK} \to \gamma\gamma$	EM, Jet, ME_T
Higgs	$W/Z\,H \to \lambda\nu \,/\, \nu\nu \, b\bar{b}$ $H \to W^{(*)}W$	EM, Jet, ME_T

L1/L2/L3 Calorimeter Trigger

- **L1 Trigger**
  - 0.2x0.2 trigger towers in EM and TOTAL, coverage to |eta| < 3.2
  - Separate readout path and Flash ADC (8-bit)
  - Run II CTFE receiver cards with adjustable gain
  - Trigger on number of towers above a threshold
    - Soon MET and Large Tiles as well
  - L1 information sent to L2

- **L2 Trigger**
  - Start with list of seed towers from L1
  - Form ET clusters of 3x3 or 5x5 towers above threshold for Jets or largest nearest neighbor towers for EM
  - Order candidates by pT

- **L3 Trigger**
  - Uses precision readout (15-bit dynamic range)
  - Run cell clustering and form reco EM and Jet objects

L2 Jets
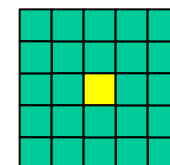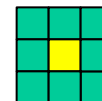
L2 EM
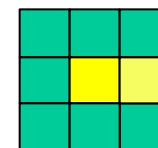
Motivation for Trigger Upgrade

Trigger	Run IIa Definition	Example Channel	L1 Rate [kHz] (no upgrade)	L1 Rate [kHz] (w/ upgrade)
EM	1 EM TT > 10 GeV	W®eν WH®eνjj	1.3	0.7
DiEM	1 EM TT > 7 GeV 2 EM TT > 5 GeV	Z®ee ZH®eejj	0.5	0.1
Muon	1 Mu Pt > 11 GeV CFT Track	W®$\mu\nu$ WH®$\mu\nu$jj	6	1.1
Di-Mu	2 Mu Pt > 3 GeV CFT Tracks	Z/y®$\mu\mu$ ZH®$\mu\mu$jj	0.4	<0.1
e + Jets	1 EM TT > 7 GeV 2 Had TT > 5 GeV	WH®eνjj tt®eν+jets	0.8	0.2
Mu + Jet	1 Mu Pt > 3 GeV 1 Had TT > 5 GeV	WH®$\mu\nu$jj tt®$\mu\nu$+jets	<0.1	<0.1
Jet+MEt	2 TT > 5 GeV MEt > 10 GeV	ZH® $\nu\nu$bb	2.1	0.8
Mu+EM	1 Mu Pt > 3 GeV + Trk 1 EM TT > 5 GeV	H®WW,ZZ	<0.1	<0.1
Iso Trk	1 Iso Trk Pt > 10 GeV	H®$\tau\tau$, W®$\mu\nu$	17	1.0
Di-Trk	1 Iso Trk Pt > 10 GeV 2 Trk Pt > 5 GeV 1 Trk matched w/ EM	H®$\tau\tau$	0.6	<0.1
Total Rate			~30	3.9
Cal Rate			4.7	1.8

Luminosity
2´10^{32}

BC
396 ns

L1 Limit
~3 kHz